

THE INTRODUCTION AND SPREAD OF *CHLOROCLYSTIS RECTANGULATA*
(L.) (GEOMETRIDAE), AND ITS FIRST REPORTED
OCCURRENCES IN THE UNITED STATES

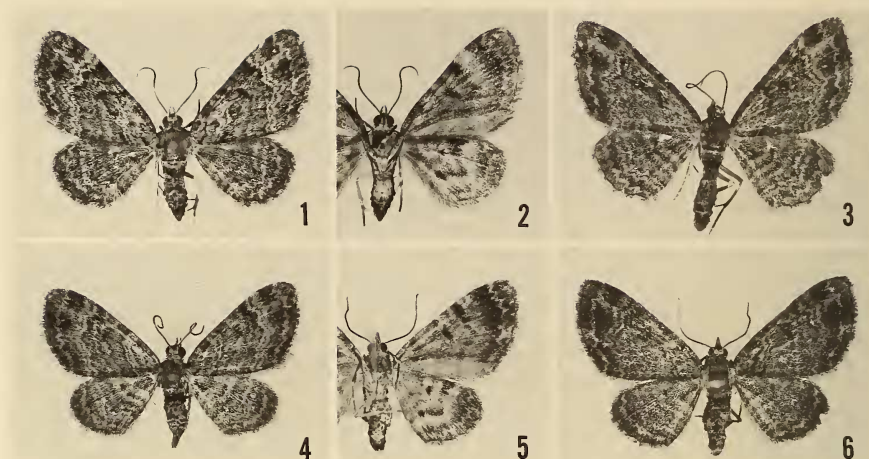
Additional key words: introduced moth, apple, pear, dispersal rate.

The palearctic fruit-tree pest, *Chloroclystis rectangulata* (L.), was first reported from North America based on Nova Scotian specimens collected at three widely separated sites in 1970 (Ferguson 1972), and the species is now generally distributed and common in that province. Between 8-18 July 1994 the senior author was able to verify the continued presence and abundance of *C. rectangulata* in Nova Scotia, where it was present at every collecting site in Yarmouth, Annapolis, Pictou, and Colchester counties. The largest numbers encountered came to light in shrubby meadowland and mixed woodland at a site southwest of Granville Ferry, Annapolis County. It apparently spread rapidly to neighboring provinces and was first reported from western Newfoundland at Stephenville in 1976 (Morris 1980:223), and from New Brunswick at Sussex, Kings County in 1978 (Neil 1980). It subsequently was collected at Doyles, southwestern Newfoundland in 1983, 1987, and 1988 by the late L. P. Grey (specimens at American Museum of Natural History), and at Pasadena, on Deer Lake, Newfoundland (reared from apple in 1982, 1983, and 1989); was found in various localities in New Brunswick in 1977, 1985, and 1987; and at Douglastown on the Gaspé Peninsula, Quebec (reared from apple, 1989) (J. D. Lafontaine, pers. comm.). It was collected at Enfield [Penobscot County], Maine every year from 1982 to 1987 by L. P. Grey (AMNH). Ten specimens were collected on Mount Desert Island, Hancock County, Maine in 1989 by G. J. Balogh, who deposited five of them in the Canadian National Collection; and one was taken at Lamoiné [Hancock County], Maine in 1991 (AMNH). Paul Grey's specimens from Enfield, Maine, 15-18 July 1982, deposited in the American Museum of Natural History (AMNH), are evidently the first records for the United States but were not reported.

Chloroclystis rectangulata recently appeared in New Hampshire and Massachusetts, having reached southern Massachusetts seven years after its first known occurrence in northeastern Maine and four years before being found in New Hampshire. However, considering the relatively few observers of small moths in Northern New England, it easily could have been present but undetected years earlier. Eight specimens were collected by the junior author at widely separated localities in four counties of Massachusetts, as follows: Truro, Barnstable County, 8 July 1989; South Dartmouth (Lloyd Center), Bristol County, 7 July 1992, 19 June 1994, 26 June 1994; Minot Road, Westminster, Worcester County, 26 June 1993; Plymouth, Plymouth County, 24 June 1993 (Fig. 3), 16 June 1994 (Figs. 1-2), 23 June 1994. One specimen was collected at Whitefield, Coos County, New Hampshire on 6 July 1993, and five more were taken at the same locality on 25 and 29 June, and on 5 and 12 July 1994 (W. J. Kiel, in litt.).

Although these records suggest that there is now a continuous distribution from eastern Canada to southern Massachusetts, major gaps remain through southern Maine and southern New Hampshire. In the absence of data from these intervening regions, it is not certain whether the Massachusetts specimens indicate a continuous range extension from Nova Scotia or a separate introduction. It should be noted that the distance from Hancock County, Maine to Whitefield, New Hampshire is nearly equal to the distance from the same point in Maine to the Massachusetts-New Hampshire border, suggesting that if the species could spread to northwestern New Hampshire, especially through or around a region of high mountains, it could just as easily have reached Massachusetts. We think it likely that the present distribution is a continuous one, and that the apparent gaps are the result of inadequate sampling.

Alternatively, this species might have been assisted by transport with agricultural products, as a hitchhiker in vehicles, or by a natural, wind-assisted, long-range dispersal event,

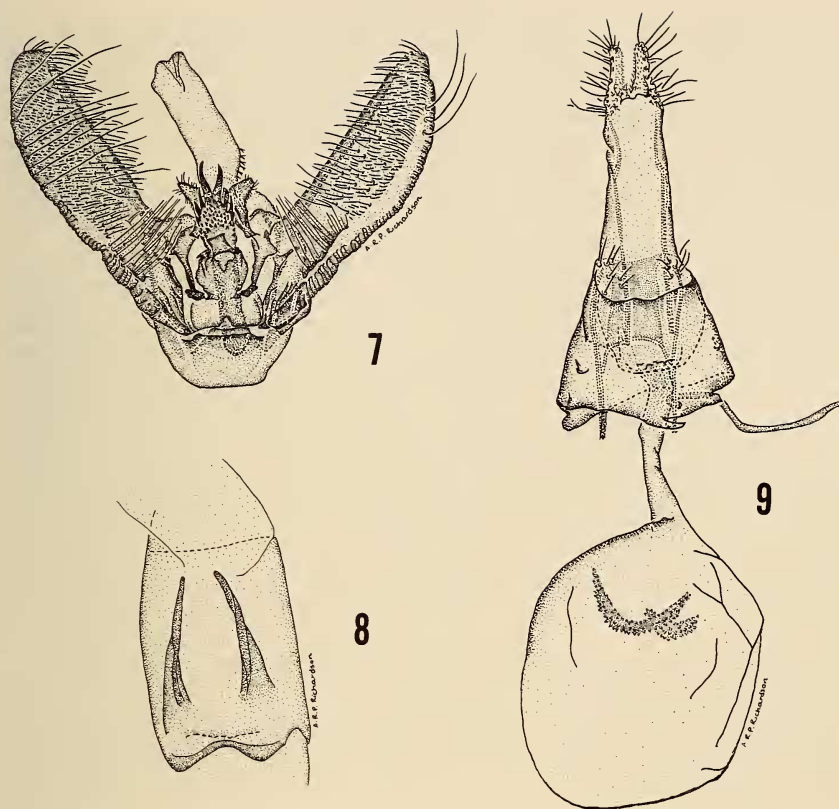


FIGS. 1-6. *Chloroclystis rectangulata* (all are females, magnification 2x). 1, Plymouth, Massachusetts, 16 June 1994. 2, same specimen, underside. 3, dark form, Plymouth, Massachusetts, 24 June 1993. 4, Granville Ferry, Annapolis Co., Nova Scotia, 8 July 1994. 5, same specimen, underside. 6, dark form, same data as Fig. 4.

although such explanations are probably not needed to account for its presence in New Hampshire and Massachusetts. The most easily transported stage would be the overwintering eggs on nursery stock, probably explaining how the species reached this continent. At this rate of spread, about 756 km from Nova Scotia to southern Massachusetts in 19 years, or 40 km/yr, *C. rectangulata* would be expected to occupy nearly all suitable habitat across the continent from a single East Coast introduction site in about 100 years; but because of an expanding West Coast population, and possibly other random dispersal events facilitated by man, the time required is likely to be less. This rate of spread (40 km/yr) is not unusual for introduced species (Ferguson, unpubl. data).

Remarkably, *C. rectangulata* appears to have been introduced almost simultaneously on the Atlantic and Pacific coasts of Canada, and is spreading outward from both sites. The Canadian National Collection contains one specimen from Victoria, British Columbia, collected in 1968, which was two years earlier than the first-reported records from Nova Scotia; and the senior author recently verified the identification of four specimens from Whatcom County, Washington. Three of these were reared from larvae on apple, and one from an unidentified tree. The species is therefore following an unexplained pattern of dual introductions noted for several other species of Lepidoptera e.g., *Thymelicus lineola* (Ochs.) (Hesperiidae), *Operophtera brumata* (L.) (Geometridae), *Leucoma salicis* (L.) (Lymantriidae), *Apamea ophiogramma* (Esp.) (Noctuidae) and *Caradrina morpheus* (Hufn.) (Noctuidae).

Ferguson (1972) remarked upon the green wing markings and the genitalic features by which this species may be distinguished but provided no illustrations. Figs. 1-6 in the present paper show adults from Nova Scotia and Massachusetts, and Figs. 7-9 illustrate the genitalia of male and female specimens from Nova Scotia. Apart from the scattered bright-green scales on the otherwise mostly dark gray-brown uppersurfaces, the heavy dark markings on the undersurfaces of both wings distinguish *C. rectangulata* from most or all North American species of *Eupithecia*. The green scales may be lost, faded or discolored in poor specimens, although the green pigment appears to be of a type more resistant to fading than most. The spinose tip of the aedeagus, with a terminal pair of large, forcepslike spines, is particularly conspicuous and diagnostic in the male genitalia;



FIGS. 7-9. Genitalia of *Chloroclystis rectangularata*. 7, ♂, Middle River, Victoria Co., Nova Scotia, 27 July 1970 (aedeagus in place). 8, same specimen, 8th sternum, 9, ♀, Baddeck Bridge, Victoria Co., Nova Scotia, 29 July 1970.

and also the weak triangular uncus is overshadowed by a very strong anal tube. In the female, the two lunate or crescentic spinulose signa, one on each side of the corpus bursae, serve to separate *C. rectangularata* from all North American members of the tribe Eupitheciini.

The life history was described by Barrett (1904:149-152), whose ten volume work is still one of the best sources of information on British Lepidoptera. The larvae feed in spring on blossoms of apple and pear, drawing the petals together and feeding within. The adults fly in June and July, and the eggs overwinter. The mature larva is short, stout, pale yellowish green, and translucent. The dorsal line is variable in color and intensity from rusty red to dark green, but may be indistinct or wanting. The spiracular (lateral) line is darker than the ground color, and the segmental divisions reddish. Younger larvae are darker, with the dorsal stripe broad, distinct, and rusty red.

Further details on the biology of *C. rectangularata* may be found in a paper by Clausen (1945), who gave references to other papers that will serve to supplement the few references provided by Ferguson (1972). The species is univoltine, and in south-central Europe the adults fly from about 29 May to late June; in Denmark they fly from mid-June to late July (Skou 1986:199), dates that are comparable to those for the Atlantic Provinces (3-29 July) and New England (16 June to 30 July). The eggs are deposited in

groups of 1–11 in crevices, fissures or injuries in the bark of twigs, branches or trunk, or under bud scales, with a preference being shown for twigs or smaller branches of 1–4 cm diameter. The eggs match the color of the bark and are not easily seen. The larvae develop within the eggs the same season and become visible through the shell 12–15 days after oviposition. However, they hibernate within the egg and do not hatch until the following spring. The eggs studied by Clausen hatched in March, and in the laboratory the larvae matured in 19–25 days on a night-day temperature cycle of 12–20°C. Outdoors under natural conditions the earliest larvae were found on 31 March and matured in 25–30 days. A forced second brood was evidently produced in the laboratory, and these larvae matured in 22–23 days. The pupal stage lasted 18–21 days under laboratory conditions.

The larvae reared by Clausen (1945) showed a definite preference for the flowers of cultivated apple and pear, feeding especially on the anthers. No attempt was made to rear them on leaves only. Those fed on pear flowers grew slightly more rapidly than those on apple. Although larvae were plentiful on pear and apple, none were found on the flowers of quince or the available varieties of plum, apricot, or cherry. Larvae that Clausen raised on those plants appeared to develop with difficulty and perished in large numbers, although in the literature there are references to *C. rectangulata* feeding on species of *Prunus*, *Crataegus*, and on quince (*Cydonia oblonga* Mill.). Most of the North American specimens were collected in or at the edges of mixed, natural woodland, not in the vicinity of orchards, and these habitats suggest that the species is thriving on native Rosaceae. Possible food plants in Nova Scotia include three native species of *Prunus* and several species of *Crataegus*, as well as cultivated or escaped pear or apple at some sites. It is not known whether native species of *Amelanchier*, *Rosa*, *Aronia*, *Sorbus*, or *Rubus* (Rosaceae) might serve as hosts.

We thank J. D. Lafontaine for providing information on specimens in the Canadian National Collection; F. H. Rindge, American Museum of Natural History, for the records from Maine in the L. P. Grey collection; W. J. Kiel of Whitefield, New Hampshire for the records from his collection; and S. Passoa, Animal and Plant Health Inspection Service, USDA, Reynoldsburg, Ohio for the records from the state of Washington. The paper was reviewed by G. J. Balogh, Portage, Michigan; C. V. Covell, Jr., University of Louisville; E. E. Grissell and R. W. Hodges, Systematic Entomology Laboratory, USDA; F. H. Rindge, American Museum of Natural History; and A. W. Thomas, Canadian Forestry Service, Fredericton, New Brunswick. The drawings are by Ann Richardson, and the photographs are by the senior author.

LITERATURE CITED

- BARRETT, C. G. 1904. The Lepidoptera of the British Islands, Vol. 9. Lovell Reeve & Co., Ltd., London. 454 pp.
- CLAUSEN, R. 1945. Observations sur la phalène anguleuse, *Chloroclystis rectangulata* L. Mitt. Schweiz. Entomol. Gesellschaft 19:611–626.
- FERGUSON, D. C. 1972. The occurrence of *Chloroclystis rectangulata* (L.) in North America (Geometridae). J. Lepid. Soc. 26:220–221.
- MORRIS, R. F. 1980. Butterflies and moths of Newfoundland and Labrador. Canadian Govt. Publishing Centre Publ. 1691:1–407. (Hull, Quebec, Canada).
- NEIL, K. 1980. The occurrence of *Chloroclystis rectangulata* (Geometridae) in New Brunswick. J. Lepid. Soc. 34:75.
- SKOU, P. 1986. The geometroid moths of north Europe. Entomonograph, Vol. 6. E. J. Brill/Scandinavian Science Press, Leiden/Copenhagen. 348 pp.

DOUGLAS C. FERGUSON, *Systematic Entomology Laboratory, PSI, Agricultural Research Service, USDA, c/o National Museum of Natural History, MRC 168 Washington, D.C. 20560 USA, and MARK J. MELLO, Lloyd Center for Environmental Studies, P. O. Box 87037, South Dartmouth, Massachusetts 02748 USA.*

Received for publication 1 May 1995; revised and accepted 8 October 1995.